

# **Apprenticeship In-school Curriculum Standards**

## **Computer Numerical Control Programmer**

**670C**



---

**Apprenticeship  
In-school Curriculum Standards**

**Computer Numerical  
Control Programmer**

670C

**POST-CERTIFICATION APPRENTICESHIP**

For the Trades Of:  
General Machinist – 429A  
Tool and Die Maker – 430A  
Tool/Tooling Maker – 630T  
Mould Maker – 431A

**Implementation date:** November 2007  
**Printing date:** June 2008

ISBN 978-1-4249-6840-4 (Print)  
ISBN 978-1-4249-6841-1 (PDF)

 Printed on recycled paper

© Queen's Printer for Ontario, 2007



## TABLE OF CONTENTS

<b>Introduction .....</b>	<b>1</b>
<b>Program Summary of Reportable Subjects .....</b>	<b>2</b>
<b>S0681      Computer Numerical Control (CNC) Technology .....</b>	<b>3</b>
S0681.1    Describe safe working procedures when setting up and operating computer numerically controlled (CNC) machines .....	4
S0681.2    Describe operating principles and applications of CNC Turning and Machining centres .....	5
S0681.3    Describe CNC dimensioning for 2 and 3 axes .....	6
S0681.4    Describe CNC machining operations .....	7
S0681.5    Describe part programming methods, set-up sheets, tooling lists, part program manuscripts, and input media .....	7
S0681.6    Describe manual operation of CNC machines .....	8
<b>S0682      Develop Geometric Forms Using of Computerized                  Aided/Assisted Design (CAD) and Computer Aided                  Manufacturing (CAM) .....</b>	<b>9</b>
S0682.1    Describe CAD/CAM system management techniques .....	10
S0682.2    Describe the capabilities of computer operating systems .....	11
S0682.3    Create basic geometric entities .....	12
S0682.4    Create geometry .....	13
S0682.5    Create 3-D geometry .....	15
S0682.6    Convert drawings to other file formats .....	16
<b>S0683      Manual Computer Numerical Control (CNC) Programming .....</b>	<b>17</b>
S0683.1    Describe the set up and application of workholding devices for CNC operations .....	18
S0683.2    Develop a plan for CNC machining operations .....	19
S0683.3    Describe the options of CNC machine systems .....	19
S0683.4    Develop CNC programs .....	20

<b>S0684.0</b>	<b>Computer Aided Manufacturing (CAM) Applications .....</b>	<b>23</b>
S0684.1	Describe the capabilities and applications of CAM technologies .....	25
S0684.2	Demonstrate use of CAM interface features .....	27
S0684.3	Generate tool path geometry .....	28
S0684.4	Generate cutter tool paths .....	28
S0684.5	Demonstrate chaining techniques for 2-D geometry .....	28
S0684.6	Describe 3-D CAM applications .....	30
S0684.7	Demonstrate the application of construction and graphic planes .....	30
S0684.8	Develop basic surfaces using 3-D geometry construction and modification methods .....	31
S0684.9	Demonstrate tool path projection techniques .....	31
S0684.10	Modify a post processor .....	31
S0684.11	Demonstrate screen modification techniques .....	32
S0684.12	Describe 3-D cutter compensation .....	32
S0684.13	Demonstrate methods for 3-D roughing and finishing .....	32
S0684.14	Demonstrate tool path optimization .....	33

## COMPUTER NUMERICAL CONTROL PROGRAMMER

### Introduction

This curriculum revision for the post-certification apprenticeship of Computer Numerical Control Programmer for the Machining and Tooling trades is based upon the on-the-job performance objectives, located in the industry-approved training standard.

The curriculum is organized into 4 reportable subjects. The Program Summary of Reportable Subjects chart summarizes the training hours for each reportable subject.

The curriculum identifies only the learning that takes place off-the-job. The in-school program focuses primarily on the theoretical knowledge and the essential skills required to support the performance objectives of the Apprenticeship Training Standards. Employers/Sponsors are expected to extend the apprentice's knowledge and skills through practical training on the work site. Regular evaluations of the apprentice's knowledge and skills are conducted throughout training to ensure that all apprentices have achieved the learning outcomes identified in the curriculum standard.

It is not the intent of the in-school curriculum to perfect on-the-job skills. The practical portion of the in-school program is used to reinforce theoretical knowledge. Skill training is provided on the job.

## COMPUTER NUMERICAL CONTROL PROGRAMMER – POST CERTIFICATION

### Program Summary of Reportable Subjects

Number	Reportable Subjects	Hours Total	Hours Theory	Hours Practical
S0681.0	Computer Numerical Control Technology	12	12	0
S0682.0	Develop Geometric Forms using Computer Aided/Assisted Design (CAD) and Computer Aided Manufacturing (CAM)	72	24	48
S0683.0	Manual Computer Numerical Control (CNC) Programming Techniques	84	24	60
S0684.0	Computer Aided Manufacturing (CAM) Applications	72	24	48
	<b>Total</b>	<b>240</b>	<b>84</b>	<b>156</b>



## COMPUTER NUMERICAL CONTROL PROGRAMMER – POST CERTIFICATION

Number: **S0681**

Reportable Subject: **COMPUTER NUMERICAL CONTROL (CNC) TECHNOLOGY**

Duration: Total 12 hours Theory 12 hours Practical 0 hours

Prerequisites: Certification of Qualifications: 429A, 430A, 431A, 630T

Content:

- S0681.1 Describe safe working procedures when setting up and operating computerized numerically controlled (CNC) machines.
- S0681.2 Describe operating principles and applications of CNC Turning and Machining centres. **(1 hr)**
- S0681.3 Describe CNC dimensioning for 2 and 3 axes. **(2 hrs)**
- S0681.4 Describe CNC machining operations. **(2 hrs)**
- S0681.5 Describe part programming methods, set-up sheets, tooling lists, part program manuscripts, and input media. **(5 hrs)**
- S0681.6 Describe manual operation of CNC machines. **(2 hrs)**

Evaluation & Testing: Assignments related to theory and application skills  
Minimum of one mid-term test during the term  
Final test at end of term  
Periodic quizzes

Mark Distribution:

Theory Testing	Practical Application Testing	Final Assessment
100 %	0%	100%

Instructional/Delivery Strategies: Lecture  
Video  
Paper based material  
CBT  
Internet On-Line

Reference Materials: CNC Technology Text Books  
CAD/CAM Programs

**S0681.0      Computer Numerical Control (CNC) Technology**

Duration:      Total 12 hours      Theory 12 hours      Practical 0 hours

Cross Reference to Training Standards: 670C: U0711 > U0720

---

**GENERAL LEARNING OUTCOMES**

Upon successful completion the apprentice will be able to describe the principles and applications of Computer Numerical Control (CNC) Technology and CNC Machining methodologies.

**LEARNING OUTCOMES AND CONTENT**

81.1 Describe safe working procedures when setting up and operating computerized numerically controlled (CNC) machines.

Identify potential safety hazards which may occur during the setting up and operation of CNC machines.

Describe safe working habits including:

- protective clothing
- protective equipment and gear
- good housekeeping
- start-up
- shut-off
- securing workpiece/cutting tools
- stabilizing workpiece/cutting tools
- lubricants
- lock-out procedures
- tagging procedures

81.2 Describe operating principles and applications of CNC Turning and Machining centres. (1 hr)

Describe CNC machines:

- types of equipment
- capabilities
- operating principles
- controls
- editing
- program path ability
- machine control unit
- personal computer systems (PC)
- direct/distributed numerical control systems (DNC)

Describe major features and functions of turning centres:

- turret
- work envelope
- holding devices
- alarms
- safety interlock
- live tooling
- accessories
- reliability
- accuracy
- repeatability

Describe the major features and functions of CNC machining centres:

- work envelope
- tool changer
- holding devices
- safety interlock
- part program
- repeatability
- accuracy
- reliability
- resolution
- accessories

## 81.2 Continued

Describe the features and functions of CNC machining centre controls:

- feeds
- speeds
- overrides
- axis selection
- mode selection
- manual data input
- handle controls
- emergency stop buttons
- cancel switches
- cycle start
- feed hold
- single block
- dry run
- machine lock
- auxiliary function lock
- graphic display

## 81.3 Describe CNC dimensioning for 2 and 3 axes. (2 hrs)

Describe the Cartesian Coordinate System:

- quadrant notation
- point location in X – Y plane
- point location in Z – X plane
- point location in Y – Z plane

Describe machine tool axis designations:

- primary linear axis
- secondary linear axis
- axis orientation

Identify types of machine zero point locations:

- fixed zero points
- full zero shift
- floating zero

Determine set-up point locations:

- machine home position
- program zero position
- tool touch-off points

81.3. Continued

Describe the capabilities of positioning and contouring:

- linear interpolation
- circular interpolation

Describe programming dimensioning practices:

- incremental
- absolute

81.4 Describe CNC machining operations. (2 hrs)

Describe fixed cycle terms and sequences:

- initial level
- R point level
- Z level
- machining increment
- rapid approach
- rapid retract
- dwell time
- feed rate

Describe the advanced specialized CNC techniques:

- high speed machining (HSM)
- thread milling
- live tooling
- additional axis
- multiple turrets
- multiple spindles
- specialized accessories
- advanced accessories

81.5 Describe part programming methods, set-up sheets, tooling lists, part program manuscripts, and input media. (5 hrs)

Identify required documentation for CNC machining processes:

- set-up sheet
  - part zero position
  - part location
- tooling list
  - tool type
  - tool number
  - tool offsets
- part program manuscript

81.5 Continued

Describe the individual components of a part program manuscript:

- sequence numbers
- preparatory functions
- axis motions
- feed rates
- spindle speeds
- tool numbers
- miscellaneous functions
- manual programming
- CAM systems
- conversational programming

Describe additional word and block structures that exist within the part program code:

- leading zero suppression
- trailing zero suppression
- decimal point programming
- block delete
- block skip
- comments

Describe the common means of producing part program files.

81.6 Describe manual operations of CNC machines. (2 hrs)

Describe manual interruption:

- single block operation
- feed hold
- emergency stop
- optional stop

Describe manual data input (MDI).

Describe override functions and applications:

- rapid motion
- spindle speed
- feedrate
- dry run

Describe interfacing to peripherals.

# COMPUTER NUMERICAL CONTROL PROGRAMMER – POST CERTIFICATION

Number: **S0682**

Reportable Subject: **DEVELOP GEOMETRIC FORMS USING  
COMPUTERIZED AIDED/ASSISTED DESIGN (CAD) AND  
COMPUTER AIDED MANUFACTURING (CAM)**

Duration: Total 72 hours Theory 24 hours Practical 48 hours

Prerequisites: Certification of Qualifications: 429A, 430A, 431A, 630T

Content:

- S0682.1 Describe CAD/CAM system management techniques. **(3 hrs)**
- S0682.2 Describe the capabilities of computer operating systems. **(3 hrs)**
- S0682.3 Create basic geometric entities. **(21 hrs)**
- S0682.4 Create geometry. **(21 hrs)**
- S0682.5 Create 3-D geometry. **(21 hrs)**
- S0682.6 Convert drawings to other file formats. **(3 hrs)**

Evaluation & Testing: Assignments related to theory and application skills  
Minimum of one mid-term test during the term  
Final test at end of term  
Periodic quizzes

Mark Distribution:

Theory Testing	Practical Application Testing	Final Assessment
33 %	67%	100%

Instructional/Delivery Strategies: Lecture  
Video  
Paper based material  
CBT  
Internet On-Line

Reference Materials: CNC Technology Text Books  
CAD/CAM Programs

**S0682.0      Develop Geometric Forms Using Computerized Aided/Assisted Design (CAD) and Computer Aided Manufacturing (CAM)**

Duration:      Total 72 hours      Theory 24 hours      Practical 48 hours

Cross Reference to Training Standards: 670C: U0711 > U0720

---

**GENERAL LEARNING OUTCOMES**

Upon successful completion the apprentice is able to develop geometric forms using computer aided/assisted design (CAD) and computer aided manufacturing (CAM) techniques.

**LEARNING OUTCOMES AND CONTENT**

**82.1 Describe CAD/CAM system management techniques. (3 hrs)**

Describe a CAD/CAM system:

- CAD/CAM functions
- capabilities of a CAD/CAM system
- handling programming data
- manipulating programming data

Identify basic computer functions and components:

- RAM - Random Access Memory
- ROM - Read Only Memory
- CPU - Central Processing Unit
- graphics card
- monitor

Identify input devices:

- keyboard
- tablet
- puck
- mouse
- scanner
- touch screen



82.1 Continued

Identify output devices:

- printers
- plotters
- monitor
- file transfer systems

Describe data storage devices.

Describe file management techniques:

- file naming
- archiving
- network accessibility
- standards conformity
- back ups

Describe menu organization:

- main menu
- history file
- text line
- task bar
- short cut keys
- macros

82.2 Describe the capabilities of computer operating systems. **(3 hrs)**

Describe naming convention of files.

Describe directory structure:

- make a directory/folder
- name a directory/folder
- change a directory/folder
- remove a directory/folder

List methods of controlling access to files.

List methods of disk and file management:

- un-delete/delete
- archive
- file compression
- copy a file
- move a file
- re-name a file

82.3 Create basic geometric entities. **(21 hrs)**

Create basic drawing entities:

- point
- line
- circle
- arc

Analyze entities for accuracy.

Create entities by entering coordinates:

- absolute
- incremental
- relative
- polar

Create entities using system features.

Modify drawing entities using editing commands:

- copy
- move
- erase
- delete
- undo
- cut
- paste
- parallel
- offset
- trim
- extend
- array
- mirror
- rotate
- change properties
- filleting
- breaking
- changing
- scaling

82.3 Continued

Create text:

- text entry
- text styles
- font selection
- custom fonts
- text placement
- text relocation
- text editing

Maintain drawing files:

- save
- save as
- open
- load
- list
- retrieve

Create drawings of machined parts for cutter paths.

82.4 Create geometry. **(21 hrs)**

Describe the concepts and properties of layers/levels:

- organization
- drawing standards
- controlling line types
- colour
- visible
- invisible
- masked

Organize drawing elements:

- create layers/levels
- assign line types
- assign colour
- turn layers/levels on and off
- freeze and mask levels/layers
- list status of layers/levels

82.4 Continued

Detail drawing dimensions:

- linear
- angular
- radial
- diameter
- ordinate
- parameters
- tolerances

Create hatch patterns:

- standard
- custom
- scale
- boundaries
- points

Import standard symbols.

Generate entities:

- rectangle
- ellipse
- polyline
- polygon
- helix
- spline
- curves
- nodes
- line width
- connecting entities
- joining entities
- editing

Verify size conformity:

- errors
- entity analysis
- coordinates of a drawing feature
- distance between two points
- area of a closed object
- perimeter of a closed object
- volume

**82.5 Create 3-D geometry. (21 hrs)**

Describe the basic elements of 3-D drawing:

- 3-D concepts
- 3-D terminology
- drawing in three dimensions
- views
- assigning colour
- rotating objects in a view
- rotating objects in space
- zooming

Construct 3-D geometry:

- standard construction planes
- name construction planes
- change construction plan
- create construction plane
- establish an origin point
- modify an origin point
- set depth
- view planes

Establish multiple views:

- single view or window
- multiple views or windows

Create 3-D objects:

- box
- cone
- sphere
- cylinder
- pyramid
- torus
- combined objects

Create 3-D solids and surfaces.

Colour surfaces:

- hide
- shade
- texture
- shadows

82.5 Continued

Edit solids and surfaces:

- extrude
- add
- subtract
- cut
- fillet
- trim

82.6 Convert drawings to other file formats. **(3 hrs)**

Export the file in other formats:

Import the file from other formats

Verify file conversion

Produce hard copy.

COMPUTER NUMERICAL CONTROL PROGRAMMER – POST CERTIFICATION

Number: **S0683**

Reportable Subject: **MANUAL COMPUTER NUMERICAL CONTROL (CNC) PROGRAMMING**

Duration: Total 84 hours Theory 24 hours Practical 60 hours

Prerequisites: Certification of Qualifications: 429A, 430A, 431A, 630T

Content:

- S0683.1 Describe the set up and application of workholding devices for CNC operations. **(6 hrs)**
- S0683.2 Prepare a plan for CNC machining. **(12 hrs)**
- S0683.3 Describe the options of CNC systems. **(6 hrs)**
- S0683.4 Develop CNC programs. **(60 hrs)**

Evaluation & Testing: Assignments related to theory and application skills  
Minimum of one mid-term test during the term  
Final test at end of term  
Periodic quizzes

Mark Distribution:

Theory Testing	Practical Application Testing	Final Assessment
33%	67%	100%

Instructional/Delivery Strategies: Lecture  
Video  
Paper based material  
CBT  
Internet On-Line

Reference Materials: Shop Text Books  
CNC Technology Text Books  
CAD/CAM Programs

**S0683.0      Manual Computer Numerical Control (CNC) Programming**

Duration:      Total 84 hours      Theory 24 hours      Practical 60 hours

Cross-Reference to Training Standard: 670C: U0711 > U0720

---

**GENERAL LEARNING OUTCOMES**

Upon successful completion the apprentice is able to demonstrate manual computer numerical control (CNC) programming.

**LEARNING OUTCOMES AND CONTENT**

**83.1    Describe the set up and application of workholding devices for CNC operations.  
(6 hrs)**

Describe features that are considered for locating and clamping the workpiece:

- raw stock
- pre-machining
- castings
- locating points
- clamping areas
- multiple parts
- fixture offsets
- quantity of parts

Describe set-up techniques of workholding devices:

- alignment to axis
- locators for multiple parts
- clamping pressures
- establishing program zero
- part geometry considerations
- hard or soft jaws
- fixtures
- tailstock
- work supports
- chucks/collets

Describe set-up procedures for CNC operations.



83.2 Develop a plan for CNC machining operations. **(12 hrs)**

List required job documentation.

Determine required CNC machine tools.

Interpret documentation.

Plan sequence of machining.

Determine workholding methods.

Determine type and application of CNC tooling.

Develop job set-up sheets by identifying:

- locating points
- workholding methods
- program zero
- axis alignment

Develop tooling list by identifying:

- tools
- tool holders
- type of tool material
- set-up dimensions
- tool numbers
- tool offsets
- cutter radius compensation register

83.3 Describe the options of CNC machine systems. **(6 hrs)**

Describe CNC machine options:

- graphic display
- in-process gauging
- stored stroke limits
- drawing dimensions input
- machining cycles
- cutting tool animation
- tool/preset probes
- part and tool verification

83.4 Develop CNC programs. (60 hrs)

Demonstrate use of preparatory commands (G-codes).

Demonstrate use of G-codes in a block:

- modality
- conflicting commands
- order

Demonstrate use of M-codes.

Demonstrate use of codes to specify dimensions:

- metric/inch selection
- absolute data input
- incremental data input
- combination in the same block
- diameter programming
- radius programming
- leading and trailing zeros input

Demonstrate use of codes to specify speeds and feeds:

- spindle rotation direction
- spindle stop
- spindle orientation
- spindle speed (RPM)
- feedrate function
- feedrate per minute
- feedrate per revolution
- override
- feedhold
- constant surface speed
- maximum spindle speed

Demonstrate use of codes to specify tool function:

- tool offset registration
- tool number
- offset number
- tool length and size
- compensation commands
- tool vectored approach
- tool description

83.4 Continued

Demonstrate use of codes to set and assign reference points:

- machine reference point
- workpiece reference point
- tool reference point
- position register command
- registry modifications
- offsets modifications
- return to machine zero
- return position check
- return from machine zero
- second machine zero

Demonstrate use of codes to define work envelopes:

- safe zones
- tool restrictions
- restricted zone
- parameters
- soft limits

Demonstrate use of codes for rapid positioning:

- positioning path
- workpiece approach
- single-axis motion
- multi-axis motion
- type of motion
- axis motion completion
- reduction of rapid motion rate

Demonstrate use of codes to create contouring programs:

- linear interpolation
- circular interpolation
- helical interpolation
- rough
- finish
- ramping

83.4 Continued

Demonstrate use of codes for radius compensation:

- cutter compensation right
- cutter compensation left
- cutter radius offset table
- cutter radius wear offset
- cutter radius value
- cutter compensation on

Demonstrate use of sub-programs and macros.

Demonstrate use of fixed machining cycles:

- fixed cycles
- drilling
- tapping
- turning
- boring
- threading
- roughing
- finishing

## COMPUTER NUMERICAL CONTROL PROGRAMMER – POST CERTIFICATION

Number: **S0684**

Reportable Subject: **COMPUTER AIDED MANUFACTURING (CAM)  
APPLICATIONS**

Duration: Total 72 hours Theory 24 hours Practical 48 hours

Prerequisites: Certification of Qualifications: 429A, 430A, 431A, 630T

Content:

- S0684.1 Describe the capabilities and applications of . CAM technologies. **(2 hrs)**
- S0684.2 Demonstrate use of CAM interface features. **(2 hrs)**
- S0684.3 Generate tool path geometry. **(8 hrs)**
- S0684.4 Generate cutter tool paths. **(8 hrs)**
- S0684.5 Demonstrate chaining techniques for 2-D geometry. **(3 hrs)**
- S0684.6 Describe 3-D CAM applications. **(3 hrs)**
- S0684.7 Demonstrate the application of construction and graphic planes. **(3 hrs)**
- S0684.8 Develop basic surfaces using 3-D geometry construction and modification. **(15 hrs)**
- S0684.9 Demonstrate tool path projection techniques. **(3 hrs)**
- S0684.10 Modify a post processor. **(2 hrs)**
- S0684.11 Demonstrate screen modification techniques. **(3 hrs)**
- S0684.12 Describe 3-D cutter compensation. **(3 hrs)**
- S0684.13 Demonstrate methods for 3-D roughing and finishing. **(15 hrs)**
- S0684.14 Demonstrate tool path optimization. **(2 hrs)**

Evaluation & Testing: Assignments related to theory and application skills  
Minimum of one mid-term test during the term  
Final test at end of term  
Periodic quizzes

Mark Distribution:

Theory Testing	Practical Application Testing	Final Assessment
33 %	67%	100%

## COMPUTER NUMERICAL CONTROL PROGRAMMER – POST CERTIFICATION

Instructional/Delivery Strategies: Lecture  
Video  
Paper based material  
CBT  
Internet On-Line

Reference Materials: Shop Text Books  
CNC Technology Text Books  
CAD/CAM Programs

## COMPUTER NUMERICAL CONTROL PROGRAMMER – POST CERTIFICATION

### **S0684.0      Computer Aided Manufacturing (CAM) Applications**

Duration:      Total 72 hours      Theory 24 hours      Practical 48 hours

Cross-Reference to Training Standards: 670C: U0711 > U0720

---

### **GENERAL LEARNING OUTCOMES**

Upon successful completion the apprentice is able to demonstrate the use of computer aided manufacturing (CAM) applications and technology.

### **LEARNING OUTCOMES AND CONTENT**

84.1 Describe the capabilities and applications of CAM technologies. **(2 hrs)**

Describe the types of CNC machining code creation capabilities of CAM software packages:

- 2-D machining
- 2 1/2-D machining
- 3-D machining
- Lathe
- Mill
- EDM
- Plasma
- Laser
- Water Jet
- Punches

84.1 Continued

Describe features of CAM software:

- interface with the user (menu driven)
- geometry module
- post processor (machine-code generator)
- communications module
- text editor
- cycle time calculations
- speed and feed calculations
- curve generation
- file size
- tool library
- material library
- comment section of the program
- interactive graphics
- feature recognition
- collision detection
- on-line help access

Describe Electrical Discharge Machine (EDM) programming:

- general functions
- EDM axes
- profile generation
- radius compensation
- graphic representation
- 4-axis
- post-processor support

Describe optional features for CAM software:

- back plotting
- family of parts programming
- macros
- conditional statements
- formula entry
- tool path simulation



84.2 Demonstrate use of CAM interface features. (2 hrs)

Manipulate the cursor between the menu area and the screen:

- cursor movement
- cursor type
- cursor shape
- item selection
- mouse buttons

Describe the CAM system menu structure:

- menu position/change
- menu customization
- short cut keys

Input commands using the command line:

- data on command line
- data entry
- menu system bypass

Identify the appearance of geometry on screen:

- selected
- unselected
- colour

Identify tool path display:

- colour identification
- rapid path
- cutting path
- direction of cutting path
- tool and holder animation
- overcut/undercut
- cusp height

Verify simulated cutter paths:

- zoom and pan features
- detail view evaluation
- on-screen regeneration

Verify geometric elements:

- size
- shape
- location
- repetition
- continuity

**84.3 Generate tool path geometry. (8 hrs)**

Create start and end points for cutting tool locations.

Demonstrate use of 2-D geometry to create cutter paths.

Demonstrate use of 2-D geometry to create chamfers and radii.

Demonstrate use of transformation functions:

- mirroring function
- rotating function
- moving function
- translating function
- copying function
- offset function
- grouping elements
- scaling elements

**84.4 Generate cutter tool paths. (8 hrs)**

Determine the axis support on the CNC machine tool and software.

Identify workholding requirements.

List and select cutting tools.

**84.5 Demonstrate chaining techniques for 2-D geometry. (3 hrs)**

Select contours for chaining by identifying:

- start position
- direction
- path
- end position
- climb milling
- conventional milling
- branch points
- z-level change

Select chains of geometry:

- entity
- automatic chaining (sequencing)
- windowing

84.5 Continued

Create cutter paths for:

- entry and exit lines
- arcs
- cutting direction
- profile modification
- cutter radius offset

Create pocketing cutter paths:

- pocket size
- pocket shape
- start point
- direction of cut
- pocket machining routine
- spiral inside out
- spiral outside in
- zig-zag
- circular direction (one way)
- finish allowance on walls
- finish allowance on the bottom
- number of pocket supports
- number of island supports
- overcut avoidance between islands
- pocket roughing

Describe the special features of CAM software:

- lettering
- tool path editing
- tool path merging
- tool path deleting
- associative tool path

**84.6 Describe 3-D CAM applications. (3 hrs)**

Describe 3-D software features:

- tool path
- cutter radius compensation
- surfaces
- projections
- surface modification
- roughing capabilities
- finishing capabilities

Compare 3-D to 2-D geometry.

Describe tool path generation methods:

- tool path without geometry
- tool path applied to defined geometry
- containment boundaries
- check surface
- restrictive boundaries
- slicing

**84.7 Demonstrate the application of construction and graphic planes. (3 hrs)**

Demonstrate use of construction planes:

- geometric planes
- top plane
- front plane
- side plane
- plane defined by two lines
- plane defined by an arc
- plane defined by a number
- plane defined by mouse movement
- saving defined planes

Demonstrate the use of graphic planes:

- changing the plane
- rotating the plane
- viewing
- names of plane

84.8 Develop basic surfaces using 3-D geometry construction and modification methods. **(15 hrs)**

Create basic surfaces using 3-D geometry construction and modification:

- swept
- ruled
- revolved
- lofted

Edit basic surfaces using 3-D geometry construction and modification:

- trim
- extend
- fillet

84.9 Demonstrate tool path projection techniques. **(3 hrs)**

Describe methods of projecting existing tool paths on to 3-D objects.

Demonstrate lettering on 3-D surfaces:

- convex
- concave
- projected
- pocketing

84.10 Modify a post processor. **(2 hrs)**

Describe the principles of post processing.

Describe the steps in post processor customization:

- variations in post processing techniques
- principles of sections
- quoted strings
- post processor versions
- verification of post processor

Develop a simple post processor.

Demonstrate use of post processor to generate CNC code.

84.11 Demonstrate screen modification techniques. **(3 hrs)**

Describe modification of the application of levels:

- masking tool paths
- hiding geometry
- adding levels
- removing levels

Demonstrate use of colour to clarify cutter path entities.

84.12 Describe 3-D cutter compensation. **(3 hrs)**

Describe the application of cutter radius compensation on surface geometry:

- compare 2-D and 3-D cutter radius compensation
- geometry chaining (sequencing)
- overcutting

Describe the application of 3-D cutter compensation:

- flat cutter
- ballnose cutter (spherical)
- bullnose cutter
- tool tip
- tool center

Select surface offset direction.

84.13 Demonstrate methods for 3-D roughing and finishing. **(15 hrs)**

Describe 3-D methods for roughing of solid materials:

- convex parts
- concave parts
- roughing a contour
- roughing with pocket levels
- step depth
- step over
- re-machining
- gap settings
- roughing routine selection

84.13 Continued

Describe 3-D methods for finishing parts:

- convex parts
- concave parts
- finishing a contour
- finishing with pocket levels
- step depth
- step over
- re-machining
- gap settings
- routine selection
- finishing routine selection

84.14 Demonstrate tool path optimization. **(2 hrs)**

Demonstrate use of filtering features to:

- reduce code length
- reduce cycle time
- eliminate unwanted points
- prevent code starvation







